The Natural Seasons of Western Oregon and Washington

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ABSTRACT

In an effort to recognize specific key dates which identify the natural seasons of the year, the thermal record of western Oregon and Washington is subjected to automated clustering techniques. Individual natural seasons of the year are recognized by the manner in which weekly temperature maxima, minima, and means are grouped using automated clustering techniques. Beginning and ending dates of the natural seasons of western Oregon and Washington are presented.

1. Introduction

The annual influence of weather and climate on the activities of mankind is frequently reduced to time units called seasons. A season is generally defined as a time period of the calendar year characterized by a particular variety of recognizably homogeneous weather. Two categories of seasons are broadly popularized: cultural and natural. The cultural seasons (flu season, soccer season, holiday season, etc.) are expressions of diverse human responses to annual temperature (and sometimes precipitation) fluctuation and are nearly innumerable. On the other hand, the natural seasons (spring, summer, fall, and winter) are calendar intervals normally distinguished by homogeneous types of weather regimes, particularly annual temperature vacillations, as well as widespread changes in general atmospheric circulation (Lamb 1950).

Of meteorological importance is the identification of individual parts of the natural calendar. Barry and Perry (1973) present the beginning dates of the natural seasons as identified and published by 11 disparate investigators. Notably, Bryson and Lahey (1958) employ sundry climatic parameters to identify 12 subseasons within the traditional 4 natural seasons. Although these, and other investigators, use the same seasonal designation, no agreement exists in the average beginning date of any natural season. Of course, the fixing of a specific beginning or ending date for any natural season on a global scale is not thought to be feasible due to the independent nature of distant climatic events across the globe (Allen et al. 1940).

2. The natural seasons

Traditionally, the "official" beginning date of each natural season is popularized by the fact that there are

four key dates marking the position on the surface of the earth (often referred to as the subsolar point) where the sun's ray is perpendicular at solar noon. In the Northern Hemisphere, the "spring" season begins at the vernal equinox on or about 21 March, at which time the sun's ray is perpendicular at the equator. The "summer" season officially arrives at the June solstice on or about 22 June, when the subsolar point is the Tropic of Cancer which marks the northernmost position of the sun's vertical ray. Occurring on or about 21 September, the autumnal equinox ushers in the "autumn" season at which time the subsolar point is again at the equator. Finally, the December solstice, on or about 22 December, signals the first day of "winter" when the subsolar point is at the Tropic of Capricorn, the southernmost position of the sun's vertical ray. The same dates apply to the Southern Hemisphere but the natural seasons are just the reverse.

Annual expressions of meteorological phenomena, however, are more variable and dynamic than to begin or end on any of these annual traditional dates. Further, within each of these four natural seasons are subseasonal vacillations of weather characteristics that constitute time periods of nonuniform seasonality. Thermal weather events that are short-term departures from monotonic seasonal trends are referred to as cold snaps and warm spells occurring within the natural seasons. Though somewhat controversial, recurrent departures from normal seasonal trends (called meteorological singularities) are so popular that weather media and atmospheric researchers continue to give them attention (Wahl 1953; Rebman 1954; Duquet 1963; Hayden 1976; Logan 1982; and Baker et al. 1983). The purpose of this paper is to report the findings of a statistical investigation of the temperature record of the Pacific Northwest in western Oregon and Washington in an effort to identify the natural seasons of this area and generally analyze the record for climatic singularities.

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3. The database

The temperature database used in this study was acquired from the National Climatic Center (NCC) in Asheville, North Carolina. Spanning a period of 28 years (1948–1975), the data consist of one daily maximum and one daily minimum temperature for each of 170 official meteorological stations located in western Oregon and Washington. The weekly mean substituted for any missing diurnal data. Figure 1 illustrates the location of the 96 meteorological stations located in western Oregon and the 74 western Washington stations used in this study.

In this statistical analysis, the basic temporal unit used is the week. For the illustrations presented in this article, the time period 1–7 January constitutes Week 01, 8–14 January Week 02, and so forth. Therefore, a single climatic event had to occur for more than five days to be significant enough to be expressed in the meteorological dataset. Daily maximum and daily minimum temperatures were averaged to obtain one weekly mean maximum and one weekly mean minimum for each station. Weekly maxima and minima were next used to calculate a weekly mean temperature for each station ($\text{mean} = \text{max} + \text{min}/2$). These procedures generated 52 weekly temperature maxima, minima, and means for each meteorological station in the study area forming the database which was then subjected to clustering techniques.

4. Statistical analysis

In order to group the variables of weekly thermal maxima, minima, and means into discrete homogeneous calendar periods, two statistical clustering techniques were employed. The fundamental goal of all clustering strategies is to obtain noncontinuous groups that have the least variability within them and the maximum differences between them. Program CLUSTER (Keniston 1978) creates similar groups by agglomeration of similar collections, or entities, which are clustered by their attributes, or characteristics. Each clustering operation may be summarized by a dendrogram of dissimilarity (Figs. 2, 3, and 4). Identical entities have zero dissimilarity and the height of an arch on the dendrogram represents the degree of dissimilarity between two clusters.

A second clustering strategy, BMDP Statistical Software (BMDP 1981), was employed to substantiate the results obtained by Program CLUSTER. BMDP cluster analysis was utilized to hierarchically amalgamate weekly temperatures into groups of greatest similarity. Beginning with 52 distinctive weeks, each step of the clustering technique joins the two most similar weeks or week clusters to form a new group until all of the weeks are in one cluster. Diagrams created by this cluster analysis closely resembled those generated by Program CLUSTER and are not presented here.

From Figs. 2, 3, and 4, a natural season is identified

FIG. 1. Location of meteorological stations employed in this study.

as a group of chronologically adjacent weeks that is found in the same cluster of weeks as a result of the clustering technique. Subseasons are recognized by sets of sequential weeks that do not cluster together at lower dissimilarities (are less identical) and meteorological singularities are seen as a solitary week that clusters nonchronologically. Due to the high degree of autocorrelation that exists in the temperature of one week to the next, it can be observed that, at relatively low dissimilarity measures, weeks of the year remain nearly statistically identical.

FIG. 2. Dendrogram of dissimilarity produced from a cluster analysis of weekly temperature maxima.

FIG. 3. Dendrogram of dissimilarity produced from a cluster analysis of weekly temperature minima.

FIG. 4. Dendrogram of dissimilarity produced from a cluster analysis of weekly temperature means.

5. Weekly maximum temperature

Figure 2 is the dendrogram created by the stepwise clustering of weekly maximum temperature. Weeks with similar temperature maxima are found side by side connected by a short arch. Seasonal week clusters are identified by longer arches representing connecting lines. The higher the arch, the greater the dissimilarity between clustered entities. The manner in which each week or set of weeks clustered is observable by inspection of the dendrograms.

To aid in the interpretation of the dendrograms, Figs. 5, 6, and 7 summarize the stepwise clustering of weekly temperatures. Each week is presented as a hexagon while weekly groups portrayed in the dendrograms are identified by connecting lines between the hexagons. Summaries of cluster groups are presented for dissimilarity measures of 20, 30, 40, and 50 in order to show the manner in which each week or set of weeks gradually clustered. With the weeks of the year arrayed in this configuration, comparisons can be made between the two extreme seasons of winter (upper portion) and summer (lower portion) and the transitional seasons of spring and autumn (center portion).

Weekly maximum temperatures display relatively large dissimilarity [measures in Fig. 2 range from 0 (the lowest statistical dissimilarity) to 180 (the highest)]. The single most cohesive season is that of winter, which continues from Week 46 to Week 10 (12 November–5 March) and spans 17 weeks. Four distinct natural seasons are not identifiable before a dissimilarity measure of 60, which represents 33 percent of the total dissimilarity between weekly clusters.

Particularly evident is the relatively long time period that is required to heat the surface of the earth after the winter season as opposed to the relatively short time required to cool the earth's surface following the summer season. For example, at dissimilarity measure of 50 (Fig. 5), the spring cluster has eight weeks (Weeks 11–18, 12 March–30 April) while the cluster representing the autumn season contains five weeks (Weeks 41–45, 8 October–5 November). Based on the manner in which maximum weekly temperatures clustered, key dates marking the beginning of each natural season are found in Table 1.

The most striking incongruous event takes place during Week 26 (25 June–1 July) when a decrease of 3°C occurs, causing the maximum temperature for this week to cluster with cooler spring-season weeks. This corroborates the findings of Craddock (1956) and others who found a cool spell in the middle to late June temperature records of Europe. Conspicuously absent is strong evidence for the very popular North American meteorological singularities called the January Thaw (middle to late January) and Indian Summer (middle to late October), which are traditional warm spells in the eastern United States.

FIG. 5. Graphic summary showing stepwise clustering of weekly temperature maxima.

6. Weekly minimum temperature

The stepwise clustering of weekly minimum temperature is summarized in Fig. 6 (deciphered from Fig. 3). Compared to weekly maximum temperature maxima, weekly temperature minima exhibit a smaller

range in dissimilarity measures (0–100) suggesting that maritime influence in this region of the Pacific Northwest is a more effective moderator of minimum temperature than of maximum temperature. Though the total dissimilarity of temperature minima is lower, temperature minima clustered in chronological order

FIG. 6. Graphic summary showing stepwise clustering of weekly temperature minima.

much less well. Temporally coherent seasons are not identifiable before a dissimilarity measure of 40, representing 40 percent of the total dissimilarity between annual minimum temperatures (Fig. 6).

At a dissimilarity measure of 50, the year is nearly equally divided into one cold and one warm season with the exception of a six-week cooling event during

Weeks 33–38 (13 August–17 September). This annual cooling event is a response to coastal upwelling during which cooler water is brought to the oceanic surface at this time of the year (Pickard 1975).

The most conspicuous singularity is a warming event of 2°C that occurs during Week 44 (beginning 29 October), causing this week to cluster anachronistically

FIG. 7. Graphic summary showing stepwise clustering of weekly temperature means.

(at low dissimilarities) with warmer summer weeks. Although this minima singularity is not evident in the weekly temperature maxima, any return to near summer warmth at this time of the year is locally known as an occurrence of Indian Summer, which is called other names in different parts of the world (Wahl 1953).

7. Weekly mean temperature

Created from the dendrogram in Fig. 4, Fig. 7 illustrates the stepwise clustering of weekly mean temperatures calculated from $(\max + \min)/2$. In terms of total dissimilarity, weekly mean temperatures display a general compromise between the grouping of maxi-

TABLE 1. The clustering of weeks based on a dissimilarity measure of 40.

Maximum temperature		Minimum temperature		Mean temperature	
Winter					
Wk 46	12 Nov	Wk 49	03 Dec	Wk 45	05 Nov
Wk 47	19 Nov	Wk 50	10 Dec	Wk 46	12 Nov
Wk 48	26 Nov	Wk 51	17 Dec	Wk 47	19 Nov
Wk 49	03 Dec	Wk 52	24 Dec	Wk 48	26 Nov
Wk 50	10 Dec	Wk 01	01 Jan	Wk 49	03 Dec
Wk 51	17 Dec	Wk 02	08 Jan	Wk 50	10 Dec
Wk 52	24 Dec	Wk 03	15 Jan	Wk 51	17 Dec
Wk 01	01 Jan	Wk 04	22 Jan	Wk 52	24 Dec
Wk 02	08 Jan	Wk 05	29 Jan	Wk 01	01 Jan
Wk 03	15 Jan	Wk 06	05 Feb	Wk 02	08 Jan
Wk 04	22 Jan	Wk 07	12 Feb	Wk 03	15 Jan
Wk 05	29 Jan	Wk 08	19 Feb	Wk 04	22 Jan
Wk 06	05 Feb	Wk 09	26 Feb	Wk 05	29 Jan
Wk 07	12 Feb	Wk 10	05 Mar	Wk 06	05 Feb
Wk 08	19 Feb	Wk 11	12 Mar	Wk 07	12 Feb
Wk 09	26 Feb			Wk 08	19 Feb
Wk 10	05 Mar			Wk 09	26 Feb
				Wk 10	05 Mar
				Wk 11	12 Mar
				Wk 12	19 Mar
				Wk 13	26 Mar
Spring					
Wk 11	12 Mar	Wk 12	19 Mar	Wk 14	02 Apr
Wk 12	19 Mar	Wk 13	26 Mar	Wk 15	09 Apr
Wk 13	26 Mar	Wk 14	02 Apr	Wk 16	16 Apr
Wk 14	02 Apr	Wk 15	09 Apr	Wk 17	23 Apr
Wk 15	09 Apr	Wk 16	16 Apr	Wk 18	30 Apr
Wk 16	16 Apr	Wk 17	23 Apr		
Wk 17	23 Apr	Wk 18	30 Apr		
Wk 18	30 Apr	Wk 19	07 May		
		Wk 20	14 May		
Summer					
Wk 19	07 May	Wk 21	21 May	Wk 19	07 May
Wk 20	14 May	Wk 22	28 May	Wk 20	14 May
Wk 21	21 May	Wk 23	04 Jun	Wk 21	21 May
Wk 22	28 May	Wk 24	11 Jun	Wk 22	28 May
Wk 23	04 Jun	Wk 25	18 Jun	Wk 23	04 Jun
Wk 24	11 Jun	Wk 26	25 Jun	Wk 24	11 Jun
Wk 25	18 Jun	Wk 27	02 Jul	Wk 25	18 Jun
Wk 26	25 Jun	Wk 28	09 Jul	Wk 26	25 Jun
Wk 27	02 Jul	Wk 29	16 Jul	Wk 27	02 Jul
Wk 28	09 Jul	Wk 30	23 Jul	Wk 28	09 Jul
Wk 29	16 Jul	Wk 31	30 Jul	Wk 29	16 Jul
Wk 30	23 Jul	Wk 32	06 Aug	Wk 30	23 Jul
Wk 31	30 Jul	Wk 33	13 Aug	Wk 31	30 Jul
Wk 32	06 Aug	Wk 34	20 Aug	Wk 32	06 Aug
Wk 33	13 Aug	Wk 35	27 Aug		
Wk 34	20 Aug	Wk 36	03 Sep		
Wk 35	27 Aug	Wk 37	10 Sep		
Wk 36	03 Sep	Wk 38	17 Sep		
Wk 37	10 Sep				
Wk 38	17 Sep				
Fall					
Wk 39	24 Sep	Wk 39	24 Sep	Wk 33	13 Aug
Wk 40	01 Oct	Wk 40	01 Oct	Wk 34	20 Aug
Wk 41	08 Oct	Wk 41	08 Oct	Wk 35	27 Aug
Wk 42	15 Oct	Wk 42	15 Oct	Wk 36	03 Sep
Wk 43	22 Oct	Wk 43	22 Oct	Wk 37	10 Sep
Wk 44	29 Oct	Wk 44	29 Oct	Wk 38	17 Sep
Wk 45	05 Nov	Wk 45	05 Nov	Wk 39	24 Sep
		Wk 46	12 Nov	Wk 40	01 Oct
		Wk 47	19 Nov	Wk 41	08 Oct
		Wk 48	26 Nov	Wk 42	15 Oct
				Wk 43	22 Oct
				Wk 44	29 Oct

maximum and minimum temperatures. Dissimilarity measures range between 0–130 and more identical weeks are made evident by the clustering of weeks at lower dissimilarity values.

Two clusters are most-coherent: a cluster of five weeks (Weeks 14–18, 2 April–30 April), which maintains its individual identity to a dissimilarity measure of 65, and a cluster of eight weeks (Weeks 25–32, 18 June–6 August), distinctive to a dissimilarity measure of 50.

In terms of unique calendar intervals, the most homogeneous natural seasons of western Oregon and Washington are spring and summer. The year is equally divided into 26 weeks of summer and 26 weeks of winter between the dissimilarity measures of 65 to 130 (Fig. 4). The midpoint of the cool season is seen to be Week 5 (beginning 29 January) while the midpoint of the warm season is Week 31 (beginning 30 July) lending strength to the wide scientific use of these months in representing the two extreme seasons.

Interestingly, Weeks 19 and 20 (7 May–20 May), which eventually become the first two weeks of the summer season, cluster early with Weeks 43 and 44 (22 October–4 November), which eventually become the last two weeks of fall. Inspection of the manner in which weekly mean temperatures clustered renders little evidence for any of the popularized meteorological singularities.

8. Conclusions

Based upon cluster analysis of weekly maximum, minimum, and mean temperature, the natural seasons of the Pacific Northwest in the United States are seen to be much more complex and numerous than merely four (Table 2). By visual inspection of dissimilarity between homogeneous weekly clusters of temperature maxima, minima, and means, the natural seasons are identified as follows:

(i) Lasting for a period of 19 weeks, the winter season with its two transitional subseasons is the longest single season (Weeks 45–11, 5 November–12 March).

(ii) Also having three subseasons, the spring season is expressed during Weeks 12–20 (19 March–14 May).

(iii) Only exceeded in length by the winter season, the summer season exists during Weeks 21–38 (21 May–17 September) and also displays two homogeneous subseasons.

(iv) The shortest of all natural seasons is fall, which consists of two subseasons between Weeks 39–44 (24 September–29 October).

With the exception of a substantial cooling event in the temperature maxima of Week 26 (25 June–1 July) and a less impressive warming event in the minimum temperatures of Week 44 (29 October–4 November), no strong evidence supports the existence of the popularized January Thaw or Indian Summer meteorological

TABLE 2. The natural seasons of western Oregon and Washington based on the combined clustering of temperature maxima, minima, and means at 30% of total dissimilarity.

Winter		Spring		Summer		Fall	
Wk 45	05 Nov	Wk 12	19 Mar	Wk 21	21 May	Wk 39	24 Sep
Wk 46	12 Nov	Wk 13	26 Mar	Wk 22	28 May	Wk 40	01 Oct
Wk 47	19 Nov			Wk 23	04 Jun	Wk 41	08 Oct
Wk 48	26 Nov	Wk 14	02 Apr	Wk 24	11 Jun	Wk 42	15 Oct
		Wk 15	09 Apr				
Wk 49	03 Dec	Wk 16	16 Apr	Wk 25	18 Jun	Wk 43	22 Oct
Wk 50	10 Dec	Wk 17	23 Apr	Wk 26	25 Jun	Wk 44	29 Oct
Wk 51	17 Dec	Wk 18	Apr 30	Wk 27	02 Jul		
Wk 52	24 Dec			Wk 28	09 Jul		
Wk 01	01 Jan	Wk 19	07 May	Wk 29	16 Jul		
Wk 02	08 Jan	Wk 20	14 May	Wk 30	23 Jul		
Wk 03	15 Jan			Wk 31	30 Jul		
Wk 04	22 Jan			Wk 32	06 Aug		
Wk 05	29 Jan						
Wk 06	05 Feb			Wk 33	13 Aug		
Wk 07	12 Feb			Wk 34	20 Aug		
Wk 08	19 Feb			Wk 35	27 Aug		
Wk 09	26 Feb			Wk 36	03 Sep		
Wk 10	05 Mar			Wk 37	10 Sep		
Wk 11	12 Mar			Wk 38	17 Sep		

logical singularities. Maritime influence in the Pacific Northwest is seen to be a more effective moderator of temperature minima than of temperature maxima. Weekly temperature minima are much less chronologically similar than are weekly temperature maxima in western Oregon and Washington.

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